human race for hundreds, and some of them for thousands, of years. They constitute the salted-down portion of human knowledge, and exhibit no life or power of growth.

The general principles (major premises) of the biological sciences are being constantly elevated to higher levels of truth through the efforts of thousands of observers and experimenters in inducting new truth.

The scientist on the farm bewilders and even disgusts the old-time farmer with his new methods of farming, but the better crops of the scientist and his greater profits in raising sheep, hogs, cattle and horses are slowly convincing the neighbor farmer that the inductive methods of the biological sciences are best. High-bred seed crops and high-pedigreed domestic animals are slowly displacing the scrub plants and animals of his ancestors. Drought loses its terrors when faced by irrigation ditches and drought-enduring seed plants. Traditions brought from a far different environment are being dispelled by the warming influence of scientific common sense.

State Normal School, Emporia.

HEREDITY AND EDUCATION.

Lyman C. Wooster.

SOME of the powers of the human mind are evidently inherited, some are developed through contact with the natural environment, and some are certainly strengthened through the agency of schools; but just what part is played by each of these agencies, and just how much the adult mind owes to each, is a question that must be answered before the worth of schools and school studies can be determined.

1. *Is life an entity with powers of its own?*

Man's first inheritance from his parents is a tiny sphere of protoplasm—a fertilized egg cell, one one-hundredth of an inch in diameter. This sphere contains what are commonly known as matter, energy, and life. The matter of protoplasm consists of carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus—six elements not at all uncommon in other forms of matter. The energy, as is well known, is obtained by oxidation of food material stored with the protoplasm in the tiny sphere. Life, the chief entity of this fertilized egg cell, is said by the vitalist to control the matter through the energy,

and is the bearer of the hereditary qualities which are to characterize the future individual.

Many physical scientists question the presence of three entities in the fertilized egg, and some go so far as to say that there is but one. The reasons given are interesting and should be briefly considered here.

Chemists and physicists teach that matter consists ultimately of atoms. The smallest sphere visible under the best compound microscope is one one-hundred-thousandth of an inch in diameter. It would require four hundred hydrogen atoms placed side by side to reach that distance. The physicists say that the atom is made up of electrons and alpha particles. Six million electrons, side by side, would extend the length of the diameter of the hydrogen atom, and fourteen alpha particles would lie on the diameter of the electron. If an atom of silver were magnified to the size of an ordinary recitation room there would be a tiny sphere in the center of the room one twenty-fifth of an inch in diameter, consisting of one hundred alpha particles and fifty electrons, and fifty other electrons circling about the room. Thus the atom is mostly betweenness. Moreover, the physicists declare that the alpha particles are units of positive electricity and the electrons units of negative electricity. But electricity is a form of energy; and matter, therefore, is but a manifestation of energy. This would reduce the number of entities in the fertilized egg to two, energy and life. Are these two one?

Starting with the atom again, we learn from the chemist and physicist that atoms unite to make molecules. They probably have a definite arrangement in the molecule, and are held together by a force known as chemism. As the molecule and its atoms are invisible under the most powerful microscope, the definite arrangement of the atoms in the molecule is merely inferred, but there are several good reasons for this inference. The combining powers and the affinities of the atom and the molecule would cause special arrangements of the several different kinds of atoms in the molecule, and then several substances like gum arabic, and cane sugar, and the cellulose and starch, have exactly the same numbers and kinds of atoms in each of these two sets of molecules. These substances have very different physical properties, hence the chemist infers that this difference is due in part to the arrangement of the

atoms in the molecule and in part to the kinds and numbers of atoms. In a similar way the molecules in crystals of various minerals are held to have a geometrical arrangement peculiar to each mineral. This geometrical form is never varied except in accordance with well-known laws, and the mineral can be recognized in all cases by the form of the crystal. The crystallographer has demonstrated that crystals grow by additions to their exterior surfaces, and naturally infers that the molecules are arranged in accordance with their fixed polarities or cohesive attractions. So far as scientists can tell, the arrangement of the molecules in crystals has nothing to do with the function to be served by such an arrangement. Indeed, one form of crystal is apparently as good as another so far as the matter of the crystal itself is concerned. Unlike energy and matter, life is a variable, and full of purpose. It, therefore, cannot be either matter or energy.

2. *Life manages matter through energy.*

Living protoplasm is a puzzle to the chemist and the physicist. They do not find in matter associated with life the certainty that exists in the mineral world. The chemist believes that there are several kinds of molecules in protoplasm, but he is not sure how many. He knows the kinds of atoms in the molecules, but he does not know the number of atoms of each kind. The living protoplasm of plant cells can manufacture sugar, starch and fats from water, carbon dioxide and sunshine, which is far more than the chemist can do. Many chemical changes, such as oxidation of sugar and fats at ordinary temperatures, are only possible to the chemist at much higher temperatures. The chemical changes wrought in digestion, assimilation, and in the preparation of a myriad organic compounds, including the proteins, are mostly far beyond the ability of the chemist to produce or induce.

In a protoplasmic cell the molecules and groups of molecules have no fixed arrangement so far as is known to the physicist, nor are the cells rigidly grouped in the tissues, nor have the tissues and organs the same arrangement in different plants and animals. Furthermore, there is ceaseless change in living protoplasm. As the work of the cell proceeds, molecules are changed in composition; matter no longer useful is excreted, and new matter is absorbed and built into the cell structure in accordance with the needs of the cell in doing its work.

Matter in protoplasm, while subject to the physical and chemical forces, is evidently ruled by a higher influence, which the vitalist terms life, and it is the varying needs of this entity which causes ceaseless change in the matter with which it is associated. Its methods of doing work are so radically different from the forces that build the crystal or that control matter in any form that it must be placed in a class far removed from that in which we place those forms of energy known as matter and electricity.

3. *What does life inherit?*

Life, while associated with what we conventionally term energy and matter, builds of the matter, through energy, tiny cells containing protoplasm in the form of nucleus, cytoplasm, and cell wall. These cells, while alive, can absorb nutriment and oxygen; make of the one more protoplasm, and use the other to release energy; excrete matter no longer useful; by an internal set of activities make an exact division of the nucleus into equal parts, and a more or less equal division of the cytoplasm and cell wall, resulting in two complete cells; receive sensations from the environment; change shape of cell; and do or not do many other things.

The human infant begins its existence as an individual the moment an active sperm cell fuses with a sluggish egg cell. Potentially, this nucleated spheroid of protoplasm, about one one-hundredth of an inch in diameter, is the future child; but the chemist could not find in its composition the slightest difference between this cell and that of a thousand other cells of both plants and animals. When the fusion of the sperm and egg cells is complete the conjugate receives nothing further from its parents, except food, oxygen, shelter, and possibly nerve suggestions from the mother, till it ends its parasitic life on the day of its birth and becomes an independent organism. In the meantime the fertilized egg cell has become many million specialized cells through subdivision and growth. It first divides and becomes two cells physically equal in all their parts, as revealed by the microscope. At this point no one could tell whether the future organism will be a plant or animal. But the next cell division decides the question, for the two cells so divide as to make a square, and not a straight line as they would have done had they belonged to the plant

kingdom. The four animal cells next so divide as to make a cube of eight cells and then these so divide as to make a sphæroid of sixteen cells, the morula stage of the embryologist.

It would not be germane to the purpose of this paper to describe in detail the successive stages of development of this little embryo. We must note, however, that the life of the embryo child must act in accordance with its inherited tendencies, and decide at the morula stage that it will not cease its development and become, perhaps, a pandorina; at the blastula stage, and become volvox; at the simple gastrula stage and be a hydra; at the bisymmetrical, three-layered gastrula stage and be a worm; at the still more complex gastrula stage, with body cavity, notocord and nerve cord, and be a fish, amphibian, reptile, or lower mammal; nor at the higher mammal stage and be an ape; but it elects to belong to the genus homo.

As the embryo child develops from the one-celled to the many-celled condition, the daughter cells take nourishment as they multiply, and the embryo child, in consequence, is many million times larger at birth than the original egg cell. The cells of the embryo become specialized in form and function as they increase in number, in accordance with inherited tendencies, those of like form and function clinging together to form tissues, and the tissues combining to produce organs of the child to be.

The list of organs acquired through heredity before birth is as long as that possessed by an adult, but the organs are smaller, and at birth nearly functionless, merely the muscles and those with vegetative functions being at all active. The babe before its birth has mouth and tongue, but no teeth and no sense of taste; it has nose and nostrils, but no sense of smell; it has eyes, but it cannot see, and ears, but it cannot hear; it has hands, but it cannot feel, and feet, but it cannot walk. The baby has a brain with a full complement of nerve cells, but it has never used them in thought, and the cells are small with few or no dendrites and axones. It has a good pair of lungs, a complete alimentary canal with associated glands, a heart with blood vessels, kidneys and various other organs—all prepared before birth with plans and specifications acquired by its ancestors, some of them millions of years before, and handed down the line from generation to generation.

The most wonderful thing in the development of the embryo from a single fertilized egg cell to a great organism possessing many millions of cells so arranged that they can do many kinds of work — that which separates living beings from lifeless minerals controlled by the physical forces—is the power possessed by life to vary its response to the condition imposed by thousands of environments so as to enable myriads of individuals to succeed in their struggles for existence. Life has succeeded or failed in its response by acting, not as chemical or a physical force, but by managing these forces as the engineer manages his engine, or as life controls its body of many parts through energy. From birth to school age the child rapidly perfects those powers it needs in its adjustment to its environment. It learns to use its organs of special sense, and the neurones of its brain, spinal cord, and other ganglia push out their axones and their complexes of dendrites as needed.

This is the time also when the boy and the girl imitate their elders in speech and conduct. They find this exercise of their growing powers so interesting that they quickly learn all forms of play known to their parents and neighbor children, and soon become expert in these forms of exercise.

When school age arrives and schools are not accessible, the children readily acquire the powers and information of parents and neighbors and become their worthy successors in all individual and social enterprises. Such men as Lincoln, for example, became great with practically no schooling. This properly raises the question as to the value of elementary schools to boys and girls. One case does not establish a principle, but it is suggestive of the direction in which the truth may lie. In pioneer days in Kansas the people of a certain district in Lyon county were unable to agree on the site for a schoolhouse. A group of about twenty children, after two years in school, were kept out of school for six years while their parents strove to agree on a site for the schoolhouse. At last an agreement was reached and the building erected. This group of boys and girls had not become school weary, but on the contrary, longed intensely for a chance to get an education. As a result of this longing, and in spite of the loss of six years of elementary school training, from this group of twenty came several district school teachers, one professor of English in a university, one professor of science in a normal school, one

doctor of divinity, one veterinarian, and one practicing physician and surgeon. Interest in this case is strengthened by the fact that no one of special note in the educational world has come from that district since. May it not be that natural abilities are too often deadened by much of the work of the public schools?

It has long been a matter of common observation that children inherit their mental as well as their physical characteristics from one or both parents. Poets and musicians are born and not made. The same may be said of mathematicians, authors and scientists.

Mechanical geniuses are without exception adepts at mathematical reasoning. That this power is inherited and not acquired by the individual is shown by the uniform testimony of those strong in mathematics and mechanics to the effect that the power to solve problems and to work with machinery runs in the family. Sporadic appearances of mathematical power in such prodigies as Tom Fuller, an illiterate African, or Jedediah Buxton, a stupid English boy, are unusual forms of heredity; but such mathematical prodigies as Zerah Colburn and the Bidders, father and son, and relatives, who were members of families noted in spots for great memory, mechanical ability and mathematical power, were well educated and are not uncommon examples of inheritance of mathematical strength.

The power to use language in a very effective way, in addition to the power to memorize the writings of others, characterizes some of the most noted American families for several generations. The Jonathan Edwards family, the Abbott family and the Beecher family readily come to mind as illustrations.

In biological science, and in its related geological science, few names occur to one, for the observational sciences are still too young to show the influence of heredity. The names, however, of Darwin, Dana and Agassiz have continued through two or three generations of remarkable achievements.

So many warriors and statesmen show the power of heredity in their history that one wonders where else they got their ability to win battles and build nations. Painters and sculptors come, almost without exception, from families and nations gifted in these lines of art. All the great musicians of Europe come from peasant stock, much of it Jewish in origin.

The inheritance of physical characteristics has long been a matter of common observation. Little use has ever been made of this knowledge of physical heredity except in cases where it may be tribal or racial. In one other field, however, the shape of the skull has been taken to furnish a clew not only to the line of parental inheritance but also to the character of the individual. Most people judge of the abilities of strangers by the shapes of their heads, as they are thought to show in a general way the shape of the brain within. This method of determining character, when carried beyond its scientific bounds, led to the temporary establishment of a pseudoscience known as phrenology. Quacks practiced it, and it soon fell into disrepute; but the writer of this paper wishes to testify that the elder Fowler gave him a character from the shape of his skull and face which was wonderfully true to life.

In more recent years the brain itself has been studied in a scientific way and the entire surface of the brain has been divided into areas having specific functions. Those areas which control the activities of muscles have been pretty definitely established, and so have likewise been located the areas of cells which organize the percepts of some of the special senses. There are, however, in each square inch about one million nerve cells, most of which are functional. At least two-thirds of the cells in man's brain (quoted from "Hall's Adolescence," part 1, page 109) have nothing to do with the organs of sense or with the muscles, but are concerned with reason, science, judgment, moral and esthetic feeling, etc. Many of the areas, therefore, have functions whose nature can, at the present state of our knowledge, be conjectured merely; and the same likewise may be true of many of the cells in the areas whose functions have been determined.

Man's nervous system is first a hollow tube made from a furrow invagination of the ectoderm of the embryo along the back. Secondly, there appear five successive enlargements of this tube near its front end. From the walls of these enlargements are developed the basic ganglia of the brain and the cranial nerves. From the front enlargement bud the hemispheres of the cerebrum. At birth the cerebral hemispheres are ready for use in meeting the diverse conditions of the child's environments. The hemispheres continue to increase in size and depth of convolutions till the age of forty or fifty. The brain cells in-

crease in size, at least those that are functional, about a thousand times; but the main bulk of the brain at all times consists of axones and dendrites—the telegraph wires; so this increase in size of the cells through use does not greatly increase the size of the brain, that of the adult weighing about three and one-half times as much as the brain of the child at birth.

The stages in the evolution of man's brain are likewise shown in the brains of his fellow vertebrates which were left behind in the race for greater efficiency. The nervous system of the lancelet is merely a tube. The brain of the fish, amphibian and reptile consists of the basic ganglia with a small cerebrum. In birds the cerebrum, for the first time among vertebrates, exceeds the other basic ganglia in volume. Among lower mammals the cerebrum so much exceeds the other basic ganglia in size that it covers the optic ganglia on the rear and the olfactory lobes in front. Furthermore the cerebrum of modern mammals far exceeds in size the same ganglion in mammals of the same size that lived two million years ago. In man the cerebrum reaches its culmination in size and covers all the basic ganglia, including the cerebellum.

No reason is known to the biologist for this increase in size and complexity of the brains of vertebrates from the lowest to the highest and through the periods of geologic time, except that they used their wits more and more in their struggles for existence, the brain culminating in size and complexity in man. As the chief growth in size of the cerebrum is in the front and rear portions, those parts whose functions are largely conjectural, it would seem to be entirely safe to assume that the thought centers, the wit centers, are located largely in these portions. But normal children possess all these centers at birth; they are merely undeveloped. The nerve cells must take nutriment, increase in size, and grow a more complex system of association fibers. The activities of the mind stimulate the growths of the brain, just as the activities of the body cause special developments of its organs.

It should not be assumed, however, that the growth of mind and brain are unlimited, for heredity says, in many cases, thus far and but little farther. Doctor Goddard of Vineland, N. J., found in his institution for the feebleminded that idiots stopped developing mentally at two or three years, in spite of best efforts of teachers; imbeciles at seven, and morons at

twelve or fifteen; and in a majority of cases he succeeded in establishing the fact that feeble-mindedness was a family inheritance that could be traced back in a number of instances for several generations; hence the limitations were an inheritance.

Morons and the average negro of full blood are short in their heredity; they lack the later acquisitions of the human race. George Oscar Ferguson, jr., of Columbia University, says, in *The Journal of Heredity* for April, 1917, p. 153, in comparing the negro and white races, that "there are no considerable group differences in sensation, in motor control, in native retentiveness. The differences to which evidence has pointed have been in such abilities as those included under the terms constructive imagination, the apprehension of meaning, reasoning power. These latter traits divide mankind into the able and the mediocre, the brilliant and the dull, and they determine the progress of civilization more directly than do the simple and fundamental powers which man has in common with the lower animals."

Even among supposedly normal children heredity imposes its limitations. A superintendent of a city of the first class in Kansas looked up the records of all the pupils who were about to enter the junior high school, and found that they must be arranged in five or six ranks of attainment if he gave them work best suited to their needs. He did not look up the records of the parents, but had he done so he would have found, undoubtedly, that the same differences existed among the families.

The only scientific inference that can be drawn from the myriad facts of heredity is that powers that man exercises are his mostly by inheritance. Since he exercises these powers through neurones, and since at birth he possesses one-half as many functional neurones as the boy of fifteen possesses, the five or six years of pre-school experience, when his mind, rapidly awakens in response to the stimuli of his environment —these five or six years, I repeat, must largely determine the character of the future man. What, then, is the province of schools in preparing boys and girls for lives of present and future usefulness?

4. *What is the province of schools?*

Schools may, perhaps, hasten the fruition of the inherited powers of mind and body, but they cannot increase materially

the upper limit of these natural powers. In spite of the utmost that schools can do, one generation stands but a trifle higher in its natural abilities than the preceding. Nothing is more certain in heredity than the claim that algebra and geometry, for example, are easily mastered because of inherited strength, and there is no conclusive proof of the assertion that these subjects increase this natural strength when mastered by the pupil. This exceedingly slow growth of all species of both plants and animals toward higher levels of efficiency, even though the species may pass through a myriad new experiences, is one of the chief arguments advanced against the doctrine of evolution. By cross-breeding and selection alone, the evolutionist answers, can desirable qualities be established and be made to dominate the herd, field or garden, within a century; otherwise millions of years would be required in accomplishing this desirable result through natural selection, development and heredity.

No educator of any prominence now believes in formal discipline. His practice may be a half century behind his knowledge of the truth, but he will no longer contend that discipline acquired in mastering one subject may be made to function in the mastery of a different subject. It is as though entirely different sets of brain cells are developed in the two lines of study, together with their own association fibers.

Schools are plainly of value, therefore, in supplementing heredity, in giving skill in the use of the physical and mental powers, and in furnishing the mind with desirable information acquired and arranged in accordance with the scientific method. Ex-President Charles W. Eliot, in the *Atlantic* for March, 1917, quotes with approval the statement that the real objects of education — primary, secondary, or higher — are, first, cultivation of the powers of observation through the senses; secondly, training in recording correctly the accurate observations made, both on paper and in the retentive memory; and thirdly, training in reasoning justly from the premises thus secured and from cognate facts held in memory or found in print. To this admirable statement of the work of schools the author of this paper would merely add that the schools must teach children how to find wholesome recreation in play, how to enjoy the best in literature, and how to get real pleasure from the fine arts. The majority of people use their

leisure times badly, and the world will be a far happier place in which to live when people learn to get their pleasures with other people and not at the expense of other people.

Only those school subjects, therefore, are valuable which function in the after lives of the pupils, increasing their wisdom to its limits, giving skill in the use of their powers of mind and body, and adding valuable information and wholesome pleasures.

Such studies will be vocational, equipping for farm and garden, business, shop, or household; personal and environmental, teaching sanitation and personal hygiene and giving skill in observation and facility in the use of the inductive or scientific method of gathering information and of reasoning; informational, supplying those past and present experiences of the race which will guide future conduct; social, making such studies of man's relationship with man as will make him a better citizen and neighbor; professional, preparing for various special lines of activity; representative, endowing the pupil with power to express thought and feeling with the tongue, pen, pencil, brush or graver's tool, and giving him the ability to understand and enjoy the thoughts and feelings of others when thus expressed; and vibrational, attuning his mind and body to the highest and sweetest harmonies of pipe, string and reed.

If this paper has seemed to overemphasize the importance of heredity and to underestimate the value of schools, the writer has not so intended. While it is true that millions of species of plants and lower animals and certain races of man and many families of the more progressive races have become nearly static, and are therefore stay-behinds in evolution, it is also true that many other species and parts of species are not yet through changing their responses to an unfavorable environment or to an increasingly favorable environment, and are constantly modifying certain parts of their bodies through disuse or increased use. Man, according to Wiedershiem ("Structure of Man," pp. 200 to 205), is modifying the structure and function of about sixty parts of his body through changed response, and is causing nearly one hundred twenty other parts to become vestigial through disuse. The nerve cells of the brain with their axones and dendrites can but be modified in a similar way through use and disuse, especially in

the formative period of childhood and youth; hence the high value of the expert direction during this time.

Whenever the same response is continued through many generations the part of the body affected by this use or disuse becomes permanently modified in heredity. The pineal body in man's brain is believed by most anatomists to be the rudiment of a third eye. This unpaired eye is still functional in certain reptiles. Mammals of two million years ago had brains far less well developed in the upper front and rear portions than the brains in mammals of the same size of body today. It should be noted that the organs of man's body originated so far back in the ancestral line and in such a simple way that they were but slight modifications of preëxisting parts. As the developing parts increased in size and efficiency through use their formation came to be more and more an unconscious function of the ego, and thus became an inheritance.

5. *But what are the proofs of the inheritance of the effects of use and disuse?*

In considering this question it must be remembered that the rate at which new modifications of parts and at which new additions or subtractions to powers pass into the domain of heredity is of necessity exceedingly slow. Persistence in use or disuse for many generations is necessary to make much change, consequently the long periods of geologic time must elapse before the modifications are very noticeable. Therefore, the geologist is the only scientist who is fitted to answer this question with assurance, and he says, after examining the fossil remains of thousands of fish, amphibians, reptiles, birds and mammals, that acquired parts are inherited and disused parts are slowly lost.

The brain cavity of mammals, for example, has increased in size several times during the Tertiary and Quaternary periods; this increase apparently keeping pace with the more and more strenuous struggles for existence, demanding the greater use of wit. Cope discovered that the primitive molar tooth of mammals was tritubercular, with simple, conical tubercles. Osborne says that nearly all kinds of mammals—hoofed quadrupeds, monkeys, carnivores, insectivores, rodents, marsupials—are found building up their grinding teeth on the basis

of this primitive tritubercular ancestral form. Indeed, there is not a part of a vertebrate's body, capable of fossilization, that does not show progressive specialization or reduction. Furthermore, the embryos of mammals, including man, in their development from the fertilized egg, repeat the stages of development of the embryos of their ancestors, from the protozoan ancestor to the present.

Progressive loss of parts is likewise shown in the skeletons of fossil vertebrates. The early Tertiary ancestor of the horse, *Eohippus*, had four toes on the front foot, and three toes on the hind foot with a rudiment of a fourth toe. Later the ancestor of the horse had but three good toes on each foot; now the horse has but one toe on each foot, with rudiments under the skin of the second and fourth toes. In all cases the modifications are inherited. The embryo of the modern horse has five toes, but four of them fail to develop.

The vitalist explains this progressive gain or loss of parts and functions by instancing the well-known fact of observation that every unusual response must be made consciously; after much repetition the act becomes habitual, and in time it is established as instinctive, and is then inherited. But it must be remembered that additional responses in the same direction keep the part growing or diminishing.

As the inherited parts and powers are ready to function very nearly in the order of their acquisition by the race, the educator needs to be a student of geology, embryology and biology as well as of pedagogy. Professor James says that most people do not realize half of their possibilities, because they do not exercise all their powers of high value even to a safe limit. This dictum has in it certainly a large measure of truth, but is it not also true that people would come more nearly to realizing their true worth if the schools had found appropriate exercise for their powers of value as they arise? Not only should the subjects studied in schools develop inherited tendencies of high value, but other tendencies of little or no worth should be allowed to become vestigial through the dropping of those school subjects which cultivate them. These latter may well include the purely formal studies of the cur-

riculum. Indeed, part of the lack in efficiency which Professor James describes may well be due to the presence in our courses of study of those subjects which seldom or never function in the after lives of the pupils. All educators are agreed that formal discipline does not count; only specific discipline is of value.

STATE NORMAL SCHOOL, EMPORIA.